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A METHOD FOR AVOIDING INSECT ROUGHNESS ON AIRCRAFT*

F. X. Wortmann **

When insects collide on fuselage and wing forward regions of aircraft, a roughness is produced which usually is large enough to immediately produce turbulence. The insect roughness therefore considerably reduces the aerodynamic performance of an aircraft. The early initiation of turbulence is especially undesirable in cases where the drag can be considerably reduced if the boundary layer is maintained laminar for an aerodynamically smooth surface. It is even more important to solve the insect problem if one wants to hold the boundary layer completely laminar by sucking it away. Methods of eliminating the insect roughness which have been proposed up to the present are all relatively costly. They essentially all amount to wing forward sections with protective coverings before takeoff, which are jettisoned or washed off at high altitudes, that is, above the insect zone. Reference [1] recently presented such methods and discussed the associated questions in detail. *** /272

It is obvious that complicated takeoff preparations could

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*** Numbers in the margin indicate pagination of original foreign text.

be carried out for long distance aircraft having boundary layer suction. For short range aircraft, which never leaves the insect zone at all or for aircraft which are only partly laminar, by the use of laminar profiles, simpler methods should be made available for solving the insect problem. According to the author, elastic surfaces represent one such possibility, because they do not allow the insect roughness to occur in the first place.

1. Effect of Elastic Surfaces

Small insects have a considerable kinetic energy at high velocities. When they impact on solid surfaces, the insect shell disintegrates and this leads to the distribution of the viscous body fluid*. If the second process can be avoided, then the first process will be negligible. Therefore in the following we will simply consider the insect to be a viscous liquid drop.

It is natural to store the impact energy for a short time in an elastic "spring" which is then used to push away the liquid drop. It is easily seen that the success of this method will essentially depend on the following parameters.

- The spring mass must be sufficiently small, otherwise the spring will not be tensioned.

- The oscillation time of the system must be so small that the viscous drop is not deformed too much during this time.

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* A hand held in a 150 km/h air stream containing fruit flies will result in pain sensations for each impact.

- The spring damping should remain sufficiently small even at high frequencies, so that sufficient energy is available for separating the drop from the wetted surface.

- The separation process should be facilitated by the poorly wetted surface.

A few motion picture photographs on the impact of liquid drops will clarify these ideas:

Figure 1 shows the impact of a water drop at a low velocity. The drop is so invicid that it disintegrates before reflection takes place.

Figure 2 shows the same process with an oil drop. In this case one can clearly see the oscillation shape of a drop. Figure 3 shows an enlargement of it. The impact energy, however, is not sufficient for separating the drop from the surface.

Figure 4 shows a few photographs of a water drop which /273 impacts at a velocity of 150 m/sec on a silicon solid rubber surface*. Now one can clearly see the reflection and the separation of the drop from the elastic surface. A small part of the drop apparently remains adhered to the surface.

2. Insect Experiments

Of course, only a few basics of the effectiveness of elastic surfaces can be determined with these few experiments in which the

* These photographs were made by E. Wieland, Dornier-System GmbH, using a high frequency camera developed by G. Hahn [2].

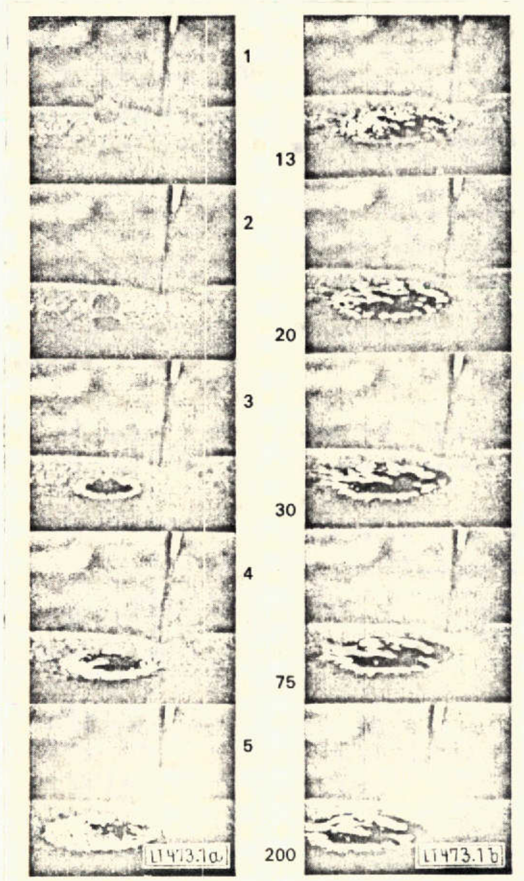
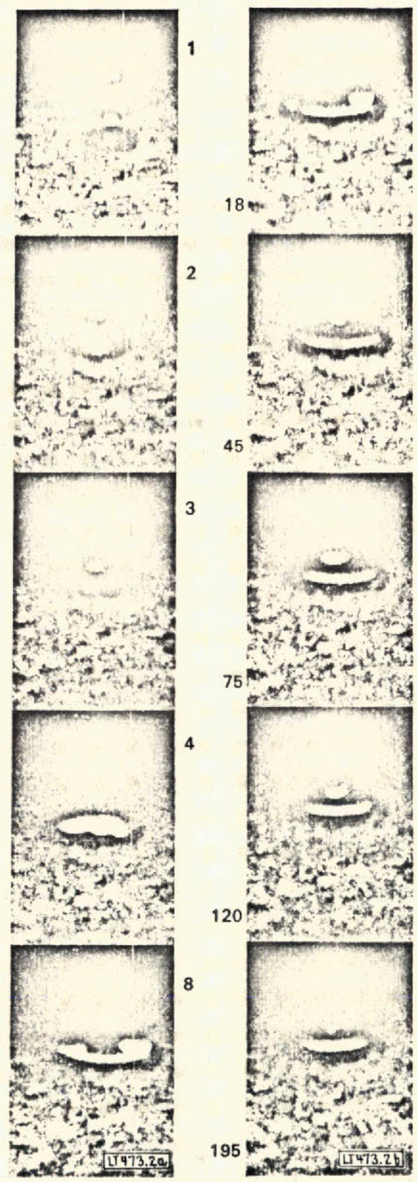


Figure 1, a and b. Impact of a water drop on a sponge rubber surface. Impact velocity about 5 m/sec, photograph frequency 6000/sec. The numbers next to the individual photographs indicate the image numbers on the film



Figures 2 a and b. Impact of an oil drop on a sponge rubber surface. Impact velocity about 7 m/sec, picture sequence 6000/sec. The numbers next to the individual photographs give the image numbers on the film

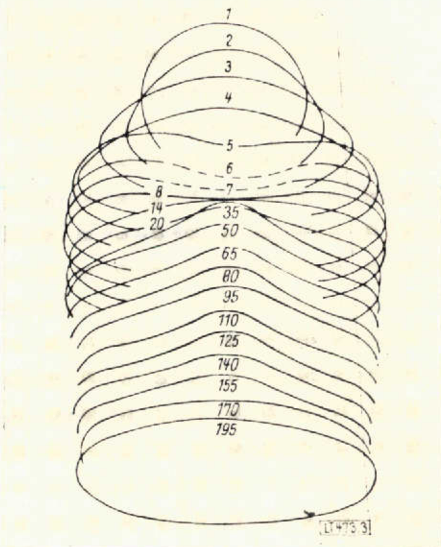


Figure 3. Contour of an oil drop for impact on a sponge rubber surface. Picture sequence 6000/sec. The numbers indicate the image numbers of the film

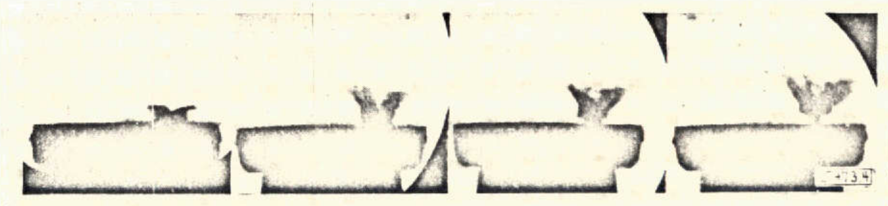


Figure 4. Reflection of a water drop during impact on a silicon rubber layer. Impact velocity about 150 m/sec. Image sequence 85000/sec. The numbers indicate the image numbers on the film

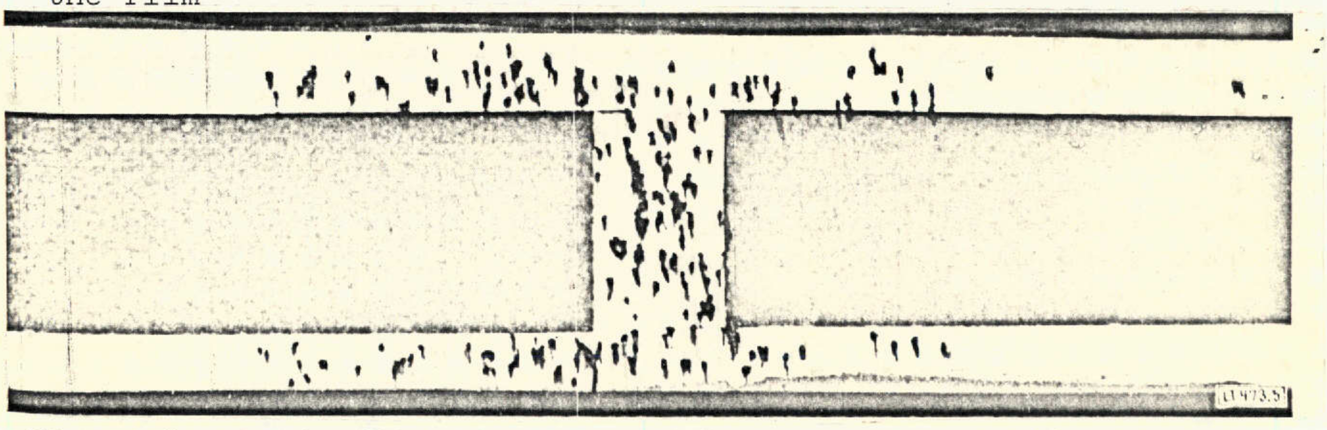


Figure 5. Fruit flies for perpendicular impact on a 3 mm thick silicon solid rubber plate. Impact velocity about 50 m/sec. The dark spots on the rubber are impact points. The wide adhesion strips are used for attaching the rubber.

insects were simulated by a liquid drop and only perpendicular incidence was considered. Therefore, additional experiments with real insects were carried out under a wide range of conditions (in the summer of 1961-1962) using different types of elastic surfaces.

The experiments soon were concentrated on solid rubber and foam rubber surfaces having a thickness between one and three mm with Shore hardnesses between 10 and 35. Figure 5 shows the typical result of a wind tunnel experiment for perpendicular impact of fruit flies against a 3 mm thick solid rubber surface. Figure 6 and 7 show the result of another wind tunnel experiment with various rubber samples and incidence angles.

In addition to these wind tunnel experiments, which are essentially restricted to a single type of fly, the fruit fly, we also attached such rubber samples to automobiles and training aircraft. Under suitable weather conditions, this could be observed for a whole day at a time. In all these experiments, we were able to determine practically no insect roughness on a few of the rubber surfaces.* However, tiny liquid traces will remain which somewhat change the optical characteristics of the surface. It therefore becomes possible to very accurately determine whether insects have impacted.

Thin rubber membranes with a thickness of about 1 mm are no longer effective at a velocity above about 100 km/h. The 3 mm thick rubber plates were satisfactory over the entire investigated velocity range, that is, between 40 km/h to about 200 km/h.

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* For aircraft with a pneumatic deicing installation made of rubber, this effect can hardly be observed because the rubber is only slightly elastic.

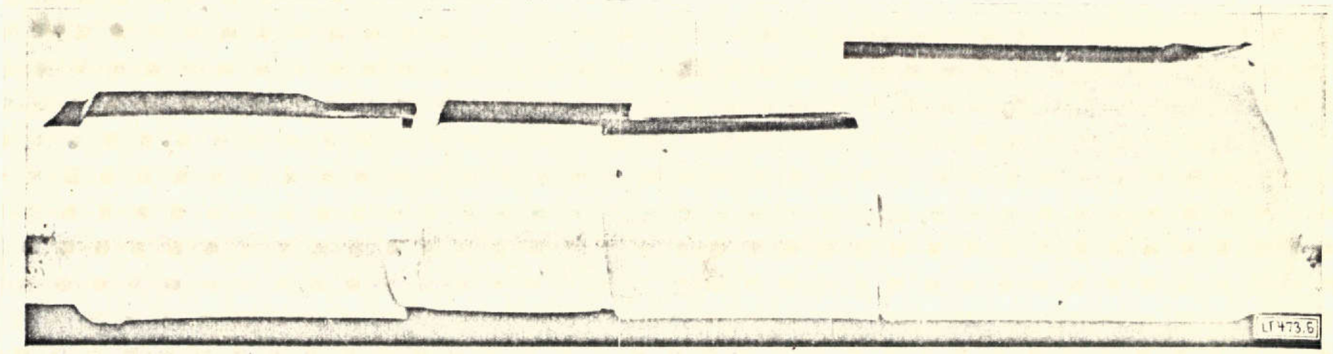

Figure 6. Testing of various rubber types for impact of fruit flies. On the right, a 3 mm thick silicon sponge rubber

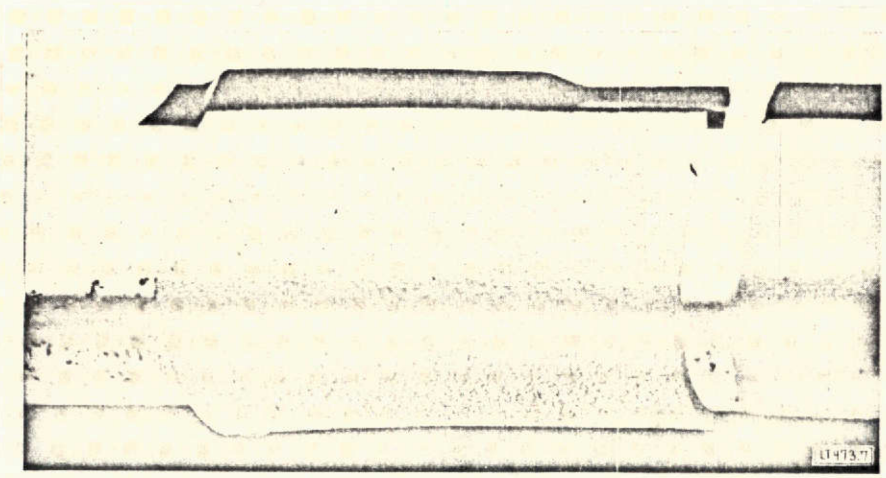

Figure 7. Enlarged segment from Figure 6. The silicon sponge rubber layer around the wing nose does not have any insect remains.

However, the liquid remains were different for the different rubber samples. This can be seen from Figure 6. For some rubber /274 samples, large liquid remains and sometimes even fly remains remained on the sample*.

* However, this was only observed for high insect density wind tunnel experiments, probably due to mutual interference during the impact process.

For other samples, especially for silicon samples or for powdered samples, only tiny traces can be observed. Silicon foam rubber was especially favorable, which has a high air fraction and a specific weight of about 0.6 p/cm^3.

In any technical application of highly elastic rubber plates for producing aerodynamically smooth surfaces, it is necessary to satisfy other requirements as well. For example, the elastic surface cannot at the same time provide icing protection, because the mass of the undercooled drops will at least in part be too small to stretch the "rubber spring". However, it is conceivable that the rubber plate can be operated like a pneumatic deicing installation, without losing its protective function against insects.

For wings with large sweepback, elastic surfaces can probably not be used because the flow can only be maintained laminar by suction which must begin at the wing tip.

In addition, a rubber layer, depending on its density, has an upper velocity limit at which rain erosion starts. For the light silicon foam rubber, this limit is reached already at a Mach number of Ma = 0.35 and for solid silicon rubber it is at about Ma = 0.6*. It is not necessary to fear a deformation because of the maximum flight stagnation pressure at subsonic velocities. Such rubber surfaces are weather protected, can easily be glued and a continuous transition between the rubber surface and the normal surface is relatively easy to produce. Therefore, we believe that this represents a simple solution to the insect problem. It will be especially important for

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* According to observations of the Dornier-System GmbH, Friedrichshafen a. B.

aircraft which primarily operate at low and moderate flight altitudes and which have a partially or completely laminar friction layer with an aerodynamically smooth surface.

Perhaps the simplicity of the proposed method will induce other people to again become interested in the possibilities of drag reduction by making the boundary layer laminar.

The author would like to thank Mr. Hamma for the wind tunnel work with fruit flies.

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16. Abstract

Insect-induced roughness on aircraft can be avoided by highly elastic rubber coverings on wing and control surface leading edges. Film photographs have shown that such elastic surfaces can elastically reflect impacting insects or viscous liquid drops. This prevents the formation of insect roughness and the endangered fuselage and wing leading edges remain smooth.

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